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APPLICATION FOR LETTERS PATENT

TITLE: ALTERNATIVE SYSTEM SWITCHING

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Description

1   The present invention relates to a broadcast receiver, in particular to a broadcast receiver capable of receiving a broadcast program via different transmission channels to select the one with the highest reception quality. Further, the present invention relates to a method to switch such a broadcast receiver from
5   one transmission channel to another transmission channel.

Alternative frequency switching strategies are widely used today, for example in FM-broadcasting. Here, a transmitter transmits a list of alternative frequencies on which transmitters at other locations transmit the same program. A receiver
10   checks the signal quality of these alternative frequencies from time to time and switches to an alternative frequency with better signal quality in case of a bad reception situation. Depending on the receiver architecture, such a switching from one frequency to another frequency is more or less audible. In a single tuner concept usually a very short program break occurs and in a two tuner
15   concept the switching is nearly not audible for the listener.

Today most radio stations do not only transmit the same program on alternative frequencies of one broadcast system, e. g. FM, but are simulcasting, i.e. transmitting the same program also on different broadcast systems, e.g. on a
20   digital system like DAB, ISDB-Tn, IBOC or DAM and FM at the same time. However, the switching from one broadcast system to another broadcast system produces big distortions today.

Therefore, it is the object underlying the present invention to provide an alter-
25   native frequency and/or alternative broadcast system switching strategy which produces less audible distortions.

According to the present invention this object is solved by a broadcast receiver according to independent claim 1 and a switching strategy defined in inde-
30   pendent claim 10. Preferred embodiments thereof are respectively defined in the respective following dependent claims. A computer program product according to the present invention is defined in claim 19.

A broadcast receiver according to the present invention comprises a first
35   tuner receiving a broadcast program on a predetermined frequency of a prede-termined broadcast system, a second tuner receiving said broadcast program

1 on an alternative frequency of said predetermined broadcast system or of an
   alternative broadcast system, and a delay unit receiving an output signal of
   said first tuner and an output signal of said second tuner to compensate a
   time delay between said both output signals.

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   Corresponding, the method to switch a broadcast receiver from a first tuner re-
   ceiving a broadcast program on a predetermined frequency of a predetermined
   broadcast system to a second tuner receiving said broadcast program on an al-
   ternative frequency of said predetermined broadcast system or of an alterna-
10 tive broadcast system according to the preent invention comprises the step of
   compensating a time delay between an output signal of said first tuner and an
   output signal of said second tuner.

   Therefore, according to the present invention a time delay between the output
15 signals of a first tuner and a second tuner is compensated. This compensation
   eliminates the effects of different receiver concepts for different broadcast sys-
   tems and different transmission or propagation times of the signal via different
   transmission channels, e.g. different frequencies of one broadcast system or
   different broadcast systems. E.g. digital receivers usually delay the audio sig-
20 nal more than analog receivers. The delay in digital receivers is caused by a
   time interleaver that is required to reduce the distortions caused by fading ef-
   fects in a mobile communication channel. Preferrably, the output signal of the
   second tuner is "shifted" so that it corresponds to that of the first tuner to
   which the user currently listens.

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   According to a preferred embodiment of the broadcast receiver according to the
   present invention additionally comprises an amplitude adaptation unit receiv-
   ing an output signal of said first tuner and an output signal of said second
   tuner via said delay unit to compensate an amplitude difference between said
30 both time delay compensated output signals.

   Corresponding, a preferred embodiment of the method according to the present
   invention additionally comprises the step of compensating an amplitude differ-
   ence between said time delay compensated output signals of said first tuner
35 and of said second tuner.

   Therefore, according to this preferred embodiment of the present invention

1   also an amplitude difference between said both time delay compensated output
     signals is compensated, preferrably so that the amplitude of the time delay
     compensated output signal of the second tuner gets adapted to that of the first
     tuner. This eliminates changes of an output level of the receiver in case of
5   switching from one broadcast frequency or system to another, since different
     amplitudes of audio signals transmitted with different broadcast systems are
     eliminated which are likely possible.

     Therewith, the present invention, in particular according to this preferred
10   embodiment, enables to switch for example from a digital system like DAB to
     another digital system like DAM or to an analog system like FM or AM without
     audible distortions in the audio signal. Therewith, the present invention allows
     a kind of broadcast system diversity to avoid distortions or loss of the audio
     signal in case of bad reception situations. According to the the present in-
15   vention the repeating of parts of the audio signal (audio frame repetition) or
     muting of the audio signal in case of bad reception situations which is widely
     used in today's digital systems, e. g. DAB, can be avoided, since audio data
     from another broadcast system or channel can be used to fill the missing
     audio data, e. g. FM-audio data can be used to fill missing DAB audio data.
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     As stated above, the broadcast receiver according to the present invention
     comprises two tuners, in particular a first tuner receiving a broadcast program
     on a predetermined frequency of a predetermined broadcast system and a
     second tuner receiving said broadcast program on an alternative frequency of
25   said predetermined broadcast system or of an alternative broadcast system.

     According to a further preferred embodiment of the present invention the time
     delay between said both output signals of the first tuner and the second tuner
     is determined by a correlation. In this case the determined correlation peak
30   describes the time delay between both output signals. Further preferably,
     respective mono signals of said both output signal of the first tuner and the
     second tuner are correlated to avoid distortions in the correlation result.

     According to a further preferred embodiment of the present invention prefera-
35   bly said output signal of the first tuner is delayed in case it advances the out-
     put signal of the second tuner and the output signal of the second tuner is de-
     layed in case it advances the output signal of the first tuner. Alternatively,

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1 also an initial delay can be provded for both output signals which ensure that also "negative" delays can be realized by relatively adjusting the delay times, i.e. "advancing" the output signal which needs the negative delay by reducing its initial delay.

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Preferably, variable delay elements are used to provide the respectively needed delay which is preferably once determined and then constantly applied, but which also can be constantly determined to avoid distortions by switching from one tuner to another tuner with a delay time which is not actual. Of course,
10 also strategies are possible according to which the delay time is determined and updated not constantly, but in regular time intervals.

In case the output signal of the second tuner, i. e. the tuner to which the broadcast receiver switches, has to be delayed a constant delay is provided at
15 once. On the other hand, in case the output signal of the first tuner has to be delayed a constant delay might be provided at once, e. g. upon switching on the broadcast receiver, or by resampling said output signal of the first tuner with a higher sampling rate, i. e. interpolation, for a predetermined period of time till the full delay is achieved and thereafter with a constant delay, or by
20 repeating a predetermined number of single audio samples of said output signal of said first tuner till the full delay is achieved and thereafter with a constant delay so that the output signal of the first tuner which is output to the user undergoes not audible or nearly not audible changes to provide the delay.

25 Furthermore, according to a preferred embodiment of the present invention the amplitude difference between said both time delay compensated output signals of the first tuner and the second tuner gets compensated on basis of a difference signal between said both time delay compensated output signals of said first tuner and of said second tuner. A subtractor which determines that dif-
30 ference signal further preferably receives a respective lowpass filtered mono signal of said time delay compensated output signals of said first tuner and of said second tuner to avoid distortions in an amplitude calculation circuit. Still further preferably, multipliers which preferably adapt the output signal of the second tuner so that an amplitude thereof equals to an amplitude of said
35 output signal of said first tuner are arranged so that the amplitude equalization can be made by minimizing the difference signal of both output signals of said first tuner and of said second tuner, i. e. the multipliers are arranged in the signal flow before the signals for the subtractor which determines the

1   difference signal are branched off.

Of course, the above described features and/or embodiments can also be com-
bined in any way to obtain an embodiment with various advantages.

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Further features and advantages of the broadcast receiver and method to
switch a broadcast receiver according to the present invention will be eluci-
dated from the following description of exemplary embodiments thereof taken
in conjunction with the accompanying

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Fig. 1   which shows a preferred embodiment of a broadcast receiver according
to the present invention.

The shown broadcast receiver according to a preferred embodiment of the pre-
15 sent invention is realized as a 2 tuner concept, namely a FM tuner 1 and a
DAB tuner 2. One tuner receives the current program, e. g. the DAB tuner 2 re-
ceives the current program transmitted in DAB (in this reception situation the
DAB tuner 2 is the first tuner). The other tuner is tuned to the same program
in another broadcast system, e. g. the FM tuner 1 receives the same program in
20 FM (in this reception situation the FM tuner 1 is the second tuner). As de-
scribed before, most likely a time difference between the audio signals of both
broadcast systems exists so that it is not possible to switch the output audio
signal from the DAB tuner 2 to a FM tuner 1 without distortions.

25 According to the present invention the time difference between both audio
signals is equalized by a delay unit 3 connected to the FM tuner 1 and the DAB
tuner 2. The time difference is calculated by correlation. Therefore, the audio
signal of the DAB signal output by the DAB tuner 2 is correlated with the audio
signal of the FM signal output by the FM tuner 1 by a correlation unit 3c. Since
30 both tuners output a stereo audio signal, preferably the mono signal (left +
right audio signal) is used for the correlation to avoid distortions in the corre-
lation result. Therefore, both parts of the output signal of the FM tuner 1, i. e.
the left audio signal and the right audio signal, are input to a first adder 3a
which outputs a mono signal corresponding to the output signal of the FM
35 tuner 1 to the correlation unit 3c. Similar, both components of the output sig-
nal of the DAB tuner 2, i. e. the left audio signal and the right audio signal, are
input to a second adder 3b which outputs a mono signal corresponding to the

1 output signal of the DAB tuner 2 to the correlation unit 3c. The correlation re-
sult, i. e. the correlation peak, describes the time delay between the DAB audio
signal and the FM audio signal. The correlation result is fed to a first control
unit 3d which controls a first variable delay element 3e arranged in the signal
5 path of the FM tuner 1 after both signal components of the output signal of the
FM tuner 1 are branched off to the first adder 3a and a second variable delay
element 3f arranged in the signal path of the DAB tuner 2 after both signal
components of the output signal of the DAB tuner 2 are branched off to the
second adder 3b.
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Depending on the sign of the time delay, the DAB output signal or the FM
output signal need to be delayed, at least relatively to each other. As mentioned
above, usually the DAB output audio signal is delayed to the FM output audio
signal due to the time interleaver arranged within the DAB tuner 2. This time
15 delay is equalized by delaying the FM audio signal by the time that is calcu-
lated in the correlation circuit.

To allow a complete distortionless switching from one tuner to the other an am-
plitude adaptation unit 4 is arranged in the signal path behind the above-de-
20 scribed delay unit 3. The amplitude adaptation unit 4 compensates an ampli-
tude difference between said both time delay compensated output signals of the
FM tuner 1 and the DAB tuner 2 which are output by the delay unit 3. This
adjustment of the amplitude is preferably performed by minimizing the differ-
ence signal between the time delay compensated output signals of the FM tuner
25 1 and the DAB tuner 2. To avoid distortions in the amplitude calculation/com-
parison, preferably the time delay compensated lowpass filtered mono audio
signals are used. Therefore, a third adder 4a receives both time delay compen-
sated output signals of the FM tuner 1 to determine the time delay compen-
sated mono audio signal of the FM tuner 1 before it is input into a first lowpass
30 filter 4c. Similar, a fourth adder 4b receives both signal parts of the time delay
compensated output signal of the DAB tuner 2 to calculate the delay compen-
sated mono audio output signal of the DAB tuner 2 before it is input to a sec-
ond lowpass filter 4d. The output signals of the first lowpass filter 4c and the
second lowpass filter 4d are input into a subtractor 4e which determines the
35 difference signal between the FM audio signal and the DAB audio signal. In the
shown embodiment the output signal of the first lowpass filter 4c is used as
subtrahend whereas the output signal of the second lowpass filter 4d is used
as minuend.

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1   The lowpass filtering has two advantages:

-   The circuit for the comparison of the amplitudes is insensitive to small time differences between the DAB audio signal and the FM audio signal, and

-   different frequency responses of the analog and digital broadcast systems
5   do not disturb the circuit for the comparison of the amplitudes: Due to the pre-emphase and de-emphase filters in combination with a limitation to a maximum frequency deviation of the FM transmitter in FM broadcast, it is not possible to transmit high frequencies in FM with the same amplitude as they are transmitted in digital systems like DAB.

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To avoid amplitude changes in the tuned audio program, only the amplitude of the alternative frequency - in this example the amplitude of the FM audio signal - is adjusted. For the adjustment the difference signal output by the subtractor 4e is input to a second control unit 4f which outputs a first control
15   signal to a first multiplier 4g and a second multiplier 4h which are respectively arranged in one part of the time delay compensated output signal of the FM tuner 1 and a second control signal to a third multiplier 4i and fourth multiplier 4k which are respectively arranged in one part of the time delay compensated output signal of the DAB tuner 2. The first to fourth multipliers
20   4g to 4k are respectively arranged in the signal paths of the output signal of the tuners before the input signals to the subtractor 4e are branched off to easily achieve an amplitude control by minimization of the difference signal.

Once the broadcast receiver has calculated the correct delay and amplification/
25   attenuation values, these values are kept constant. The receiver can now switch from one tuner to the other, i. e. from the DAB tuner 2 to the FM tuner 1 without audible distortions. The switching is performed by a switching unit 5 which is connected after the amplitude adaptation unit 4 and which receives both components of the time delay compensated amplitude adjusted output
30   signal of the FM tuner 1 and both components of the time delay compensated amplitude adjusted output signal of the DAB tuner 2 to select both components of one thereof as audio output signal.

As elucidated above, this technique can be used to switch from DAB to FM, e.
35   g. in case of a bad reception situation for DAB. The receiver can switch from DAB to FM for example depending on the error rate. Whenever the DAB tuner 2 has a high error rate or loses synchronization, the receiver switches from DAB tuner 2 to the FM tuner 1 to avoid distortions or interruption of the audio sig-

1   nal. The switching time period could be as short as just a few audio samples or an audio frame.

In the following a second reception situation is elucidated according to which
5   the broadcast receiver shown in Fig. 1 switches from the FM tuner 1 (in this reception situation the FM tuner 1 is the first tuner) to the DAB tuner 2 (in this reception situation the DAB tuner 2 is the second tuner).

In case of reception of an FM program, the receiver switches automatically to
10   DAB to receive the best audio quality. Therefore, according to the present invention the timing and the amplitude of the FM audio signal and the DAB audio signal are equalized. As also mentioned above, generally the DAB signal is delayed to the FM signal due to the time interleaver comprised in the DAB tuner 2. Therefore, the DAB signal would have to be delayed with a negative
15   delay in case the FM signal should be left undelayed, which is of course not possible. Therefore, the FM audio signal has to be delayed although this signal is currently heard by a user. Therefore, the following three control strategies are advantageously implemented within the first control module 3d.

20   1.   The FM signal is delayed at once. This can e. g. be done at the beginning, when the listener tunes to the FM station. Therefore, the receiver needs to know the delay between the FM audio signal and the DAB audio signal and needs to delay the FM audio signal with this delay. This information can be stored in the memory of the receiver. Information is calculated once and
25   stored in the receiver like it is done today with the station name in some FM receivers. Another possibility is to delay the audio signal once and to accept that the audio signal is disturbed once. A further possibility is to provide delay lines for both tuners and to tap the output signals e.g. in the middle of each delay line so that also "negative" delays are possible for the
30   output signal of the second tuner.

      2.   The FM signal is delayed by resampling the audio signal with a higher sampling rate (interpolation) for a limited time period. The interpolation with a small interpolation factor is not audible. The same effect can be achieved by reduction of the audio DAC (digital to analog converter)
35   sampling rate for a limited time period.

      3.   A simple method repeats the single audio samples in the audio data. In other words, the delay is changed slowly. The distortions are almost not audible - depending on background noise, e.g. determined via the speed of

1   a car in which the reciver is used, the delay is changed.

As indicated in the general description of the present invention, a broadcast
receiver according to the present invention can of course also be used to switch
5   from one digital system to another digital system. There is no limitation to
switch from DAB to FM and vice versa. Of course, also a switching to other sys-
tems like AM, DRM, ... is possible.

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